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Numerical Analysis of meteor impact and its explosion in Chelyabinsk, Russia

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A meteoroid penetrating the atmosphere exploded in Chelyabinsk, Russia in February 2013. This event was the most energetic terrestrial impact phenomena witnessed by human beings, since Tunguska event of 1908. Some videos recorded the entry of the meteoroid and its explosive phenomena. They indicate details of the trajectory and the magnitude of the explosion. The meteor traveling at a velocity of approximately 18 km/s penetrated the atmosphere at the shallow angle of 20 degree from the ground. The bolide exploded with the maximum brightness at the altitude of about 20 km, and was broken up into some fragments. The collected fragment indicates that it is an ordinary chondrite. The diameter and the mass of the original meteoroid are estimated to be 17-20 m and ~ 10 ktons, respectively.

It is important to figure out the mechanics of the bolide impact on the earth, and the resulting effect on the Earth's atmosphere and the surface, as the event affects human activities. In order to understand the mechanics of the interaction of a meteoroid and the atmosphere, the subsequent shock wave expansion, and the thermal conditions of the meteoroid and the atmosphere, numerical simulations using SPH (Smoothed Particle Hydrodynamics) are conducted.

As initial conditions of simulations, the ideal gas and Tilltoson EOS are applied to the atmosphere and the meteoroid, respectively. The density and the impact velocity of a meteoroid are 2700 kg/m^3 and 20 km/s, respectively. Since, the strength of a meteoroid is not taken into account, the disruption or the fragmentation of a meteoroid cannot be observed in our simulations.
Preliminary results indicate that the atmospheric dynamic pressure at the stagnation point of the meteoroid becomes a few tens MPa at the altitude of ~ 20 km. The velocity and density differences between the melted surface of the meteoroid and compressed atmospheric flow along the meteoroid result in the instabilities on the surface. They grow around the stagnation point, and then melted fragments are ejected to the gas flow. This might be one of the processes of meteoroidal ablation.

Keywords: meteoroid, impact, impact cratering, shock wave